Renewable and Sustainable Energy Reviews 16 (2012) 113–122

Contents lists available at SciVerse ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Review of solar obligations in China

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ARTICLE INFO

Article history:
Received 2 May 2011
Accepted 5 July 2011
Available online 14 September 2011

Keywords:
Solar obligation
Solar water heater
China

ABSTRACT

Solar energy utilization can not only decrease conventional energy consumption but also reduce environmental pollution. China has abundant solar energy resources and has the biggest solar water heater market in the world, so it is necessary for Chinese government to enact incentive policies and measures to enlarge the utilization scale of solar water heaters. According to international experience, solar obligation is probably the most powerful instrument for promoting the use of solar thermal in buildings and expanding the solar water heater market. Currently, there are many provinces and cities in China having adopted the solar obligation, leading to the discussion of solar obligation at national level. This paper firstly analyzed basic conditions to implement the solar obligations in China. Then, 34 provinces and cities' local regulations were reviewed and main problems of them were analyzed. According to domestic and international practices, some recommendations for the design and implementation of solar obligations at national level were induced at the end.

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Contents

1. Introduction

Energy supply and security play a vital role in the national economical development. In China, total energy consumption increased from 571.44 million tons of coal equivalent (tce) in 1978 to 3.25 billion tce in 2010, and the percentages of coal in primary energy production and consumption were more than 67% during this period [1,2]. The total energy consumption in 2010 was 3.25 billion tce, increasing 5.9% compared with the previous year, thereinto, the consumption of coal, crude oil, natural gas and electricity reached 3.18 billion tons (the growth rate of 5.3%), 0.43 billion tons (the growth rate of 12.9%), 104.8 billion m^3 (the growth rate of 18.2%) and 4182 terawatt-hours (TW h) (the growth rate of 13.1%) respectively [2]. The inappropriate energy structure of China has brought a series of environmental problems, hence Chinese government attached great importance to control greenhouse gas emissions. In order to improve the inappropriate energy structure and seek a balance among economic development,

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doi:10.1016/j.rser.2011.07.140

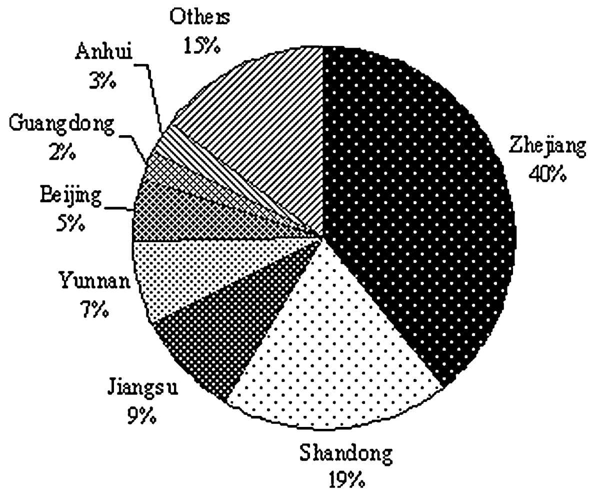


Fig. 1. The SWH enterprise share of different province and city at the end of 2009 [4].

energy supply, and environmental protection, it is important to find alternative energy. The renewable sources, such as solar energy, wind energy, geothermal energy, ocean energy, and biomass, are regarded by Chinese government and ordinary people. Chinese government therefore established Renewable Energy Law in February 2005, which was expected to act as the guarantee and special emphasis on the subject of renewable energy development, and began to subside programs on solar water heaters (SWHs), solar photovoltaic systems and geothermal heat pumps. In September 2007, Chinese government set a binding target of 15% for the renewable share of total energy consumption by 2020 [3]. On November 26 of 2009, the State Council announced that China was going to reduce the intensity of carbon dioxide emissions per unit of gross domestic product in 2020 by 40–45% compared with the level of 2005. These created a strong pressure to implement more effective policies able to deliver the necessary growth rates at national level.

SWH has been proved to be reliable and economical in cases of hot water production. Currently, China has become the biggest SWH production and utilization country in the world. The accumulative yield of solar collectors at the end of 2009 reached 145 million m^2 [4]. In this context, China has a lot of experience in the SWHs market. However, as a country with the population of 1.3 billion, the square meters of solar collectors per thousand people reached 107 at the end of 2007, much lower than 897 m^2 in Cyprus, 745 m^2 in Israel and 341 m^2 in Austria [5]. So the population of residential SWHs in China still covers a small percentage of households, and the potential market should be far from saturation point. According to international experience, solar thermal obligation is probably the single most powerful instrument for promoting the use of solar thermal energy in buildings and expanding the SWH market. The first solar thermal obligation was enacted in Israel in 1980, as an answer to the worries about security of energy supply in the aftermath of the second oil crisis. In the light of governmental sources, today Israel saves circa 8% of its electricity consumption thanks to solar heating systems [6]. It took two decades before the next one was adopted in Barcelona. The first solar obligation ("Ordinance") was approved by the City Council in 1999, and entered into force in August 2000. After some years of experience, the Ordinance was modified, and the new version entered in force in 2006. After the first Ordinance entered into force, 21.7 MW_{th} (31,050 m^2) solar thermal capacity had been added in Barcelona by the end of 2005, producing 24,480 MW h of solar energy per year. These solar thermal systems allowed for savings of 4368 ton CO_2 [6]. At present, solar or renewable heat obligations were in force or in advanced state of discussion in a growing number of European countries, regions and cities. Outside of Europe, solar obligations are being discussed in Tokyo, one federal state in Brazil, and some Australian federal states.

After the implementation of Renewable Energy Law, solar obligations were adopted by some local governments in China, such as Shandong, Jiangsu, Yunnan, Zhejiang and Shenzhen. Since these regulations were enforced, local solar thermal industries have grown, and more citizens and potential users were informed about SWHs. The rising tide of local regulations triggered an ongoing discussion at national level. Thus, the aim of this study was to give a systematic overview and suggestions based on the available experience and on fundamental conditions for the implementation of solar obligation in China. Such information would be useful to design policies at the national level most suitable to accelerate the growth of solar thermal, as needed to reach the China's binding target of a 15% renewable share by 2020.

2. Basic conditions for the implementation of solar obligations in China

2.1. Solar energy resources in China

According to the data of Chinese Weather Bureau, the total solar energy resources are enormous in large area, but the irradiation is various in different zones, as shown in Table 1. Over 90% of China's territory has an annual solar irradiation above 4500 MJ/m^2, so China has abundant solar energy resources.

2.2. SWH industry in China

Chinese SWH industry is rapidly developed in the recent decades. China has become the biggest SWH production, sale and holding country in the world. The holding accumulative total and annual yield of SWH from 1998 to 2009 are listed in Table 2. By the end of 2009, the annual yield of SWHs reached 42 million m^2 with the growth rate of 35.5%, and the total sale of SWHs reached 57.85 billion yuan, increasing 34.5% than the last year [4].

Two types of SWHs dominated in China: flat-plate collectors and evacuated tubular collectors. There were three manifold-types of evacuated tubular collectors: all-glass, heat-pipe, and U-tube. The annual yield of SWHs was 42 million m^2 in 2009, including 40 million m^2 of evacuated tubular collectors and 2 million m^2 of flat-plate collectors. In the total yield of evacuated tubular collectors, the all-glass type had a share of 94%, followed by heat-pipe type of 4% and U-tube type of 2%.

To date, SWH industry chain has begun to take shape in China, including raw material processing, product development and manufacturing, engineering design and marketing service. There were more than 2800 SWH enterprises at the end of 2009, including 4 manufacturers with an annual output value above 2 billion yuan and 1 manufacturer with an annual output value of 1 billion yuan [4]. The SWH enterprise share of different province and city in China is shown in Fig. 1. About 1100 SWH enterprises were located in Zhejiang, ranking the first within all provinces. 540 SWH enterprises were located in Shandong, ranking the second, followed by Jiangsu with 250 enterprises.

2.3. Existing renewable energy policies in China

The renewable energy has been regarded by the Chinese government in the past 10 years, and the Chinese government formulated a series of laws and regulations to encourage renewable energy utilization, including the application of solar thermal energy.

Renewable Energy Law of the People's Republic of China had been confirmed in 28 February, 2005 and entered into force in

Table 1
Four zones of solar radiation in China [7].

Zone No.	Solar availability	Annual irradiation (MJ/m^2)	Annual sunlight (h)	Region	Percent of soil area (%)
I	Very abundant	>6700	3200–3300	Most of Tibet, south of Xinjiang, west of Inner Mongolia, west of Gansu, west of Qinghai	17.4
II	Abundant	5400–6700	3000–3200	Most of Xinjiang, east of Gansu, east of Qinghai, Ningxia, Shanxi, Shaanxi, Hebei, Beijing, Tianjin, northeast of Shandong, east of Inner Mongolia, Yunnan, west of Sichuan	42.7
III	Available	4200–5400	1400–3000	Heilongjiang, Jilin, Liaoning, Anhui, Jiangxi, south of Shaanxi, Shandong, Henan, Zhejiang, Jiangsu, Hubei, Hunan, Fujian, Guangdong, Guangxi, Shanghai, Hainan, south of Guizhou	36.3
IV	Poor	<4200	1000–1400	Sichuan, Guizhou, Chongqing	3.6

January 1, 2006. Article 17 stipulates that (i) the state encourages units and individuals to install and use SWHs, solar heating and cooling system, photovoltaic generation system and other solar energy utilization systems. (ii) The construction administration department and other relevant departments under the State Council should enact technical-economic policies and technical norms for the integration of solar thermal systems with buildings. (iii) According to above technical norms, real estate enterprises should provide necessary conditions for the use of solar energy during the design stage and construction stage of buildings. At this year, to effectively implement this law, Ministry of Housing and Urban-Rural Developing (MOHURD) and Ministry of Finance (MOF) jointly issued Implementation Opinions on Promoting the Utilization of Renewable Energies in Buildings, Interim Measures on the Administration of Special funds for Renewable Energy Buildings and Implementation Plans for City Demonstration of the Application of Renewable Energy Buildings in succession. Since the implementation of these regulations, the application of renewable energies in civil buildings has developed rapidly. At the end of 2010, there were 581 demonstration projects, 47 demonstration cities and 98 demonstration counties for the renewable energy utilization [8].

Energy Conservation Law of the People's Republic of China was amended in October 28, 2007. Article 40 stipulates that the state encourages using energy efficient building materials (such as new type wall materials) and equipment and installing renewable energy systems (such as solar energy systems) in new buildings and existing buildings. Energy-Conservation Ordinance of the Civil Construction, enforced in October 1, 2008, also stipulates that the state encourages using renewable energy (such as solar energy and geothermal energy) in the new buildings and existing buildings, and that in regions with the access to solar radiation, local governments and relevant departments shall take effective measures to encourage and support units and individuals to install solar thermal systems, such as solar hot water systems, solar lighting systems, solar heating systems, solar cooling systems (Article 4).

In addition, the National Development and Reform Commission issued the National Implementation Program for Promoting Solar Thermal Application in April 2007, which clearly stated that Chinese government will formulate solar obligations at national level.

2.4. Existing technical standards and quality certification system

To increase the implementation of the Renewable Energy Law, MOHURD issued the national standard-Technical Code for Solar Energy Application of Civil Buildings in December 5, 2005, and has implemented in January 1, 2006. This standard was the technical basis of solar water heating systems integrated with civil buildings. Thereafter, a series of national and departmental standards were published, as shown in Table 3. These standards set detailed technical requirements for the quality of solar products, their installation and maintenance. It can be seen that the national standard system for the solar thermal use has been initially established in China. In addition, 16 local governments also formulated local standards to assure the quality and the proper working of the solar water heating systems, such as Beijing, Yunnan, and Jiangsu.

At the same time, the supervision and inspection for the quality of solar products has been strengthened, and the certification scheme has been developed initially. The General Administration of Quality Supervision, Inspection and Quarantine of China and the Certification and Accreditation Administration of China (CNCA) authorized three national solar heater supervision and

Table 2
The holding accumulative total and annual yield of SWH from 1998 to 2009 [4].

Year	Annual yield (10^4 m^2)	Annual growth of yield (%)	Holding accumulative total (10^4 m^2)	Annual growth of holding (%)
1998	350	–	1500	–
1999	500	43	2000	33
2000	640	28	2600	30
2001	820	28	3200	23
2002	1000	22	4000	25
2003	1200	20	5000	25
2004	1350	12.5	6200	24
2005	1500	11.1	7500	21
2006	1800	20	9000	20
2007	2300	30	10,800	19.7
2008	3100	32.5	12,500	15.7
2009	4200	35.5	14,500	16

Table 3
Technical standards for the use of solar thermal energy.

Standard and its number	National	Ministry	Implementation date
Solar energy-Thermal application-Terminology GB/T 12936-2007	√		2007-10-01
Solar thermal collectors			
All-glass evacuated solar collector tubes GB/T 17049-2005	√		2005-11-01
Glass-metal sealed heat-pipe evacuated solar collector tubes GB/T 19775-2005	√		2005-11-01
Evacuated tube solar collectors GB/T 17581-2007	√		2008-06-01
Test methods for the thermal performance of solar collectors GB/T 4271-2007	√		2008-06-01
Flat plate solar collectors GB/T 6424-2007	√		2008-06-01
Technical Requirement for Environmental Labeling Products-Domestic solar water heating system HJ/T 362-2007	√		2007-12-01
Solar water heating systems			
Test methods for thermal performance of domestic solar water heating systems GB/T 18708-2002	√		2002-10-01
Solar water heating systems-design, installation and engineering acceptance GB/T 18713-2002	√		2002-11-01
Specification of domestic solar water heating systems GB/T 19141-2003	√		2003-10-01
Technical code for solar water heating system of civil buildings GB/T 50364-2005	√		2006-01-01
Assessment code for performance of solar water heating systems GB/T 20095-2006	√		2006-09-01
Technical Requirement for Environmental Labeling Products-Domestic solar water heating system HJ/T 363-2007	√		2007-12-01
Technical code for solar heating system GB 50495-2009	√		2009-08-01
Selection and installation of central solar water heating systems 06SS128 (GJBT-960)	√		2006-12-01
Design and installation of solar collector systems 06K503 (GJBT-965)	√		2006-12-01
Accessories			
Solar water heaters-elastomeric materials for absorbers, connecting pipes and fittings-method of assessment GB/T 15513-1995	√		1995-12-01
Electric auxiliary thermal source for domestic solar water heaters NY/T 513-2002		√ (MOA)	2002-12-01
Storage water tank for domestic solar water heaters NY/T 514-2002		√ (MOA)	2002-02-01
Polyethylene of raised temperature resistance pipe for solar water heating system CJ/T 318-2009		√ (MOHURD)	2010-06-01

MOA, Ministry of Agriculture of the People's Republic of China.
MOHURD, Ministry of Housing and Urban-Rural Developing of the People's Republic of China.

inspection centers, located in Beijing, Wuhan and Kunming respectively. Since 2004, these centers have randomly checked the quality of SWHs and played a good role in regulating the SWH market. In term of Article 20 and Article 21 in Energy Conservation Law, CNCA has approved three third-party certification organizations for SWHs since 2005. They are China General Certification Center (CGC mark), China Environmental United Certification Center (China Environment Labeling) and Certification Center of China Academy of Building Research (CABR mark).

In view of these conditions, solar obligations have been adopted or are being discussed in a number of provinces and cities in China.

3. Local regulations including solar obligations in China

With the growing general interest of local authorities in promoting the use of solar thermal energy in civil buildings, some local incentive policies associated with solar thermal were published one after another.

Regulation on Building Energy Conservation of Shenzhen Special Economic Zone was the first local policy including solar obligation in China, and was promulgated in July 26, 2006. The correlative items contain: (i) new 12-story below residential buildings which have the conditions for solar collection are obliged to install solar hot water systems by construction units. (ii) If new 12-story below residential buildings have no conditions for solar collection, construction units must apply for the exemption from the municipal competent departments during the building being applied for construction. These provisions were enforced in November 1, 2006. Xingtai was the second city adopting the solar obligation in 2007. Currently, solar obligations have been adopted in 34 cities and provinces. These policies were reviewed here. Beijing's solar thermal policies were financial incentives, so not included in this review.

Details of these policies are displayed in Table 4 and listed by enforcement dates and provinces. It can be seen from them that:

(i) In most policies, new 12-story and below residential buildings and new public buildings demanded a lot of hot water, such as hospitals, schools, hotels, public baths, should be subject to the obligation. Only Shenzhen, Xingtai and Kunming stipulated that all new residential buildings should be included in the obligation. Obliged shares were only mentioned in Notice of strengthening the popularization and administration of solar water heating systems (Jiangsu), namely the share of solar energy needed to produce hot water should be more than 60% in new residential buildings. Exemptions were not analyzed and not included in Table 4 because only Regulations of Nanjing on Building Energy Conservation mentioned that historical buildings and sites can be the exception to solar obligations. In addition, most policies encourage installing solar water heating systems in existing buildings invested by local government and popularizing SWHs in rural residential buildings.

(ii) All of these local polices did not include the word of "mandatory" or "obliged", however, they clearly stipulated that if without the design of solar hot water system, the construction planning permit for the obliged building must not be approved by local construction administrative departments and that if not installing solar hot water system, the obliged building must

Table 4
Summary of local regulations including solar obligations.

Province/Municipality	Document (enforcement date)	Types of obliged buildings	Sanction	Support measure	Local standard
Guangdong Province					
Shenzhen	Regulations on Building Energy Conservation of Shenzhen Special Economic Zone (2006-11-01)	New 12-story below residential buildings	√	T[a], A	PS[b]
	Work Programme of developing city demonstration projects of renewable energy utilization and implementing the Solar Roof Plan in Shenzhen (2010-12-01)	New civil buildings with the demand of hot water; existing dormitories and inpatient departments which have the install conditions for solar systems	√	F, T, A, D	PS
Zhuhai	Procedures on the administration of building energy saving of Zhuhai (2009-08-01)	New 12-story below residential buildings	√	FD, T, D	PS
Hebei Province					
Xingtai	Notice of the full popularization of solar water heating systems in civil buildings (2007-01-01)	New low-rise and multi-storied residential buildings, villas and hotels (including the renovation and extension)		FD, T, A, D	PS
	Notice of speeding up the popularization and application of solar water heating systems (2007-10-10)	New multi-storied residential buildings; buildings demanded a lot of hot water, such as hospitals, schools, hotels, indoor swimming pools, public paths		F	PS
	Opinions on the popularization of solar water heating systems in high-rise buildings (2010-04-01)	New 12-story above residential buildings; civil buildings with the demand of hot water, such as hospitals, schools, hotels, indoor swimming pools, and public baths		F	PS
Qinhuangdao	Notice of the full popularization of solar energy integrated with civil buildings (2007-09-01)	New 12-story below residential buildings (including the renovation and extension); new public buildings (directly invested or subsidized by the governments) with the demand of hot water, such as schools, hospitals, and factories			PS
Hebei Province	Notice of the implementation of solar water heating systems integrated with civil buildings (2008-11-01)	New 12-story and below residential buildings; public buildings demanded a lot of hot water, such as hospitals, schools, hotels, indoor swimming pools, public baths			PS
Shijiazhuang	Measures of Shijiazhuang on the administration of civil building energy saving (2008-11-01)	New government office buildings; other public buildings (including the renovation), such as hotels, public baths, schools, hospitals	√	T	PS
	Opinions on the implementation of promoting the large-scale utilization of renewable energy in buildings (2010-05-27)	New 12-story and below residential buildings; other buildings demanded a lot of hot water, such as hospitals, schools, hotels, indoor swimming pools, public baths		F, T, D	PS
Henan Province					
Sanmenxia	Notice of the popularization of solar water heating systems integrated with civil buildings (2007-03-01)	New 12-story below residential buildings (including the renovation)			PS
Zhengzhou	Notice of the popularization of solar energy use in civil buildings (2008-09-01)	New 12-story and below residential buildings and hotels (including the renovation and extension); public buildings with the demand of hot water, such as hospitals, schools, indoor swimming pools, public baths			PS
Kaifeng	Notice of strengthening the utilization of renewable energy in civil buildings (2009-07-01)	Buildings demanded a lot of hot water, such as hospitals, schools, hotels, indoor swimming pools, public baths			PS
Liaoning Province					
Shenyang	Notice of further promoting the solar energy utilization in civil buildings (2007-08-01)	New low-rise and multi-storied residential buildings and villas (including the renovation)			PS
Zhejiang Province					
Zhejiang Province	Measures of Zhejiang Province on Administration of Building Energy Conservation (2007-10-01) and Opinions on the utilization of solar energy in buildings (2007-12-12)	New 12-story and below residential buildings; new 12-story and below public buildings with the demand of hot water	√	FD, T, A, D	PS
Ningbo	Measures of Ningbo Municipality on Administration of Civil Building Energy Conservation (2010-08-01)	New public buildings with the demand of hot water; new 12-story below residential buildings	√	FD, T, A, D	PS
Heilongjiang Province					
Heilongjiang Province	Notice of the popularization and application of solar water heating systems in civil buildings in the whole province (2007-10-01)	New multi-storied residential buildings and villas (including the renovation)			

Table 4 (*Continued*)

Province/Municipality	Document (enforcement date)	Types of obliged buildings	Sanction	Support measure	Local standard
Jiangsu Province					
Jiangsu Province	Notice of strengthening the popularization and administration of solar water heating systems (2008-01-01)	New residential buildings (the share of solar energy needed to produce hot water should be more than 60%); public buildings such as hotels, hospitals, schools		FD, T, A, D	PS
	Administrative measures of Jiangsu for building energy saving (2009-12-01)	New public buildings with the demand of hot water, such as hotels, commercial–residential buildings; new 12-story below residential buildings	√	FD, T, A, D	PS
Nanjing	Notice of forwarding the notice of strengthening the popularization and administration of solar water heating systems (2008-03-03)	New 12-story and below residential buildings; new public buildings demanded hot water (including the renovation and extension), such as hotels, commercial–residential buildings			PS
	Regulations of Nanjing on Building Energy Conservation (2011-01-01)	New 12-story below residential buildings; new public buildings with the demand of hot water (including the renovation and extension)	√	FD, T, A, D	PS
Suzhou	Administrative measures for civil building energy conservation of Suzhou (2008-05-01)	New 12-story and below residential buildings; new public buildings with the demand of hot water (including the renovation and extension), such as hotels, hospitals	√	FD, T, A, D	PS
Hubei Province					
Wuhan	Instruction opinions on promoting the utilization of solar water heating systems in the new buildings (2008-04-01)	New 12-story and below residential buildings; hospitals, dormitories, hotels, fitness centers, swimming pools, and government buildings which have conditions for solar collection			
Yunnan Province					
Yunnan Province	Notice of speeding up the normative utilization of solar water heating systems (2008-05-01)	New 11-story below residential buildings; new 24-m below public buildings with the demand of hot water		A	PS
Kunming	Notice of strengthening the management of utilizing solar water heating systems in civil buildings of Kunming (2008-06-01)	New 12-story below residential buildings (including the renovation and extension); public buildings demanded a lot of hot water, such as dormitories, hotels, kindergartens, gymnasium, hospitals, nursing homes, orphanages, indoor swimming pools, public baths			PS, MS
	Regulations of Kunming on the administration of integrating solar water heating systems with civil buildings (2010-04-17)	New residential buildings which have the conditions for solar collection; new hotels, dormitories, hospitals, nursing homes, kindergartens, government buildings, and other buildings invested by the government (including the renovation and extension)	√		PS, MS
Shangdong Province					
Yantai	Opinions on the popularization and application of solar water heaters and complete technology in residential buildings (2007-01-30)	New low-rise and multi-storied residential buildings			
	Implementation opinions on speeding up the popularization and application of solar technology (2010-02-10)	New 12-story and below residential buildings and villa (including the renovation and extension)			
Jinan	Implementation opinions on speeding up the popularization of solar water heating systems in residential buildings of Jinan (2008-08-09)	New low-rise and multi-storied residential buildings (including the renovation and extension)		T, A	PS
Dezhou	Notice on speeding up the promotion and utilization of solar energy (2008-11-28)	New residential buildings (including the renovation and extension); public buildings with the demand of hot water, such as hotels, hospitals, schools, indoor swimming pools, public baths			PS
Weihai	Administrative provisions of the promotion and utilization of solar water heating systems in civil buildings of Weihai (2009-01-01)	New 12-story and below residential buildings; new public buildings with the demand of hot water, such as hospitals, hotels, schools, office buildings, indoor swimming pools, public baths			PS
Shandong Province	Interim Measures of Shandong Province for Administration of Financial Subsides for Solar Collector Systems (2009-01-22) and Notice of opinions on implementation of popularizing and utilizing solar light/thermal systems (2009-10-25)	New 12-story and below residential buildings (including the renovation and extension); public buildings with the demand of hot water		FD, D	PS

Table 4 (*Continued*)

Province/Municipality	Document (enforcement date)	Types of obliged buildings	Sanction	Support measure	Local standard
Qingdao	Regulations on Building Energy Conservation of Qindao (2010-01-01)	New 12-story below residential buildings; public buildings with the demand of hot water, such as hospitals, schools, hotels, indoor swimming pools, public baths	√		PS
Shanxi Province					
Taiyuan	Implementation opinions on promoting the renewable energy utilization in civil buildings (2008-11-19)	New 12-story below residential buildings (including the renovation); new public buildings with the demand of hot water (including the renovation and extension), such as hotels, commercial- residential buildings		F, T	
Anhui Province					
Hefei	Notice of the implementation of the local standard of Anhui Province—Technical standards for the solar energy utilization and building integration (2009-03-01)	New 12-story and below residential buildings; new public buildings with the demand of hot water (including the renovation and extension), such as hotels, commercial–residential buildings			PS, MS
Tongling	Notice of strengthening the utilization of renewable energy in civil buildings (2010-01-01)	New 12-story below residential buildings; public buildings with the demand of hot water which are invested by the government			PS
Qinghai Province					
Qinghai Province	Provisions of Qinhai Province on the administration of the popularization and application of solar water heating systems in civil buildings (2009-11-01)	New residential buildings which have installation conditions for solar water heating systems; other buildings demanded a lot of hot water, such as hospitals, schools, restaurants, indoor swimming pools, public baths		FD, A, D	PS
Fujian Province					
Fuzhou	Notice of strengthening the popularization and application of renewable energy in civil buildings (2010-01-01)	New 12-story below residential buildings (including commercial–residential buildings)		FD, D	PS
Ningxia Province					
Ningxia Province	Administrative measures of Ningxia Hui Autonomous Region for the utilization of solar water heating systems in civil buildings (2010-01-01)	New 12-story below residential buildings, dormitories and apartments (including the renovation); new public buildings with the demand of hot water (including the renovation and extension), such as government office buildings, hospitals, schools, kindergartens, hotels, public baths		FD, T, D	PS
Yinchuan	Notice of popularizing the utilization of solar building integration (2010-01-01)	New 12-story below residential buildings			PS
Hainan Province					
Hainan Province	Administrative measures of Hainan for the utilization of solar water heating systems in buildings (2010-03-01)	New 12-story and below residential buildings (including the renovation and extension); public buildings, such as dormitories, hospitals, hotels, restaurants, public baths	√		PS
Shanghai Municipality					
Shanghai	Regulations of Shanghai Municipality on Building Energy Conservation (2011-01-01)	New public buildings with the demand of hot water; new 6-story and below residential buildings	√	FD, D	MS

[a] F, financial subsides; A, awareness raising; T, incentive training; D, demonstration projects; FD, financial subsides only for demonstration projects.
[b] PS, local standards at province level; MS, local standards at municipality level.

not pass the completion acceptance. At the same time, most policies established corresponding controlling procedures for the design, construction and acceptance of solar water heating systems, such as Jiangsu, Hainan, Yunnan (Kunming), Anhui, Zhejiang, etc. For example, Kunming's regulations proposed the Five-Synchronize administrative system, namely the solar water heating system should be planned, designed, constructed, accepted, and put into use simultaneously with the main project of buildings. To effectively implement theses controlling procedures, sanctions were applied in 12 provinces and cities' regulations. For example, Bureau of Housing & Construction of Shenzhen Municipality enacted Administrative Sanction Standards of Regulations on Building Energy Conservation of Shenzhen Special Economic Zone after the implementation of regulations.

(iii) 11 provinces and cities adopted three or four flanking measures. Xingtai was the first local government adopting financial subsides for all obliged buildings, followed by Taiyuan, Shijiazhuang, and Shenzhen. For instance, according to the new policy of Xingtai (issued in 2010), Opinions on the popularization of solar water heating systems in high-rise buildings, a full reduction of the auxiliary cost for city construction should be granted for new 12-story above building installed solar hot water system, and a 50% reduction of auxiliary cost for city construction should be granted for new 12-story and below building installed solar hot water system. According to the New policy of Shenzhen (issued in 2010), Work Programme of developing city demonstration projects of renewable energy utilization and implementing the Solar Roof Plan in Shenzhen, the subside, for solar water heating systems installed in buildings excluding new 12-story and below residential buildings, low-income housings, and others invested by governments, is 375 yuan per square meter of solar collectors, including 150 yuan supported by central special funds and 225 yuan supported by municipal special funds.

(iv) After enacting mandatory policies for the use of solar thermal, some provinces and municipalities promulgated the supplemental documents and technical standards successively to make the mandatory policy more detailed and more operational. Regulations of Shenzhen, Xingtai, Jiangsu (Nanjing), Shijiazhuang, Yantai and Yunnan were modified after some time of experience, and new versions entered into force. In addition, 13 provinces and 3 municipalities enacted local technical standards for the design, installation, and acceptance of solar water heating systems.

Generally speaking, above local policies have promoted the use of solar thermal energy and have expanded the local SWH markets to some extent, especially in Kunming, Xingtai, Shenzhen, Jiangsu, Shandong, Anhui, Zhejiang and Hainan. For example, after the first solar obligation came into forth in June 2008, the number of solar thermal enterprises in Kunming increased to 118 at the end of 2009, and the popularizing rate of SWHs reached 30% [9]. Since the first regulation included solar obligations was approved and entered into force in January 2007, Xingtai has become the first Solar Building City in China. By the end of 2008, the total area of buildings integrated with solar energy reached 2.84 million m^2 and the popularizing rate of SWHs in new completed-buildings reached 100%. Meanwhile, the output value of solar energy industry (including SWHs and photovoltaic) in Xingtai achieved 5.63 billion yuan during the first half of 2008, and increased by 115% [10]. In addition, the constructions companies in above provinces and cities became used to include solar thermal system at the earliest stage of planning, thus reducing the time and costs needed to integrate it at a later point. Citizens and potential users were informed about solar. Beyond local effects, lessons from these experiences will be useful for the design and implementation of regulations to promote the use of solar thermal at national level.

4. Problems and recommendations for solar obligations at national level

As mentioned above, many cities and provinces in China have adopted the solar obligation to promote the solar thermal use, but only several acquired good results of the implementation. Meanwhile, the solar obligation at national level is being discussed in China due to local practices. Main problems existing in local policies and recommendations for the design and implementation of solar obligations at national level were analyzed in terms of five areas as followed.

4.1. Contents of the solar obligation

Solar obligations are regulations requiring a minimum share of the heating demand be covered by solar energy. A complete solar obligation, therefore, should include four components: buildings subject to the obligation, exemptions, definition of the required solar contribution, and calculation method of the fulfillment.

In 8 provinces and municipalities, solar obligations applied to new residential buildings and those undergoing the renovation or extension. In others, obligations applied not only to the residential sector but also to some public buildings. The latter was recommended for a national solar obligation because of many public buildings consuming a lot of hot water and with good conditions for solar collection, such as hotels, hospitals, indoor swimming pools, schools, sport facilities, public baths.

The required solar contribution is essential for any solar obligation. However, all of above regulations except Jiangsu Province's did not defined the minimum share of solar energy needed to produce hot water and procedures for its calculation. Most foreign obligations required at least 30–70% of the domestic hot water demand from solar energy. These cannot be applied to China directly, because the climatic condition, technical level, economic level and people's living standard in China are different from those in foreign countries. In order to be applicable to all obliged buildings in the whole of China, the required solar contribution should be defined moderately after consulting related professional associations (including building administrators, constructors, architects, engineers, installers, solar and renewable energies and others), the local, regional and national energy agencies, as well as government/public bodies responsible for housing, urban planning, and protection of architectonic heritage and environment. Once the required share of solar energy is established, calculation method of the fulfillment must be defined. To simplify the legal text, technical detail of the calculation method can be provided in local or national standards.

In addition, a clear list of conditions allowing for exceptions was not provided by any provinces and municipalities except Nanjing. The frequent exemptions of foreign solar obligations include historic buildings and buildings where other renewable energy sources are used, or with limited access to solar radiation, which are recommended for China.

4.2. Enforcement procedures and sanctions

Without enable enforcement procedures and clear sanctions, a solar obligation makes little sense. The implementation of solar obligations should be controlled by the public authorities at the planning stage of the obliged building, during the construction/installation and before the building is put into use. These enforcement procedures were more or less clearly provided by all of local regulations as above mentioned. Are these enough? During the first phase of implementation of a solar obligation, low compliance is more likely due to the scarce knowledge or willingness within construction companies. Besides above procedures, therefore it is recommendable to random inspect a sample of systems installed under the obligation to see if they perform in accordance with requirements after a period of operation. If the knowledge level of relevant companies and personal as well as the awareness of the users and citizens increase after some years of experience, the frequency of inspections can be reduced.

Even though enforcement procedures adopted, the implementation of solar obligations could be unsuccessful because of lacking the sanctions. As above-mentioned, only 12 provinces and cities' regulations provided sanctions, moreover, many of them were unclear and/or too low. For construction companies and/or building developers, in this case, no or low compliance may be a rational option, and they will attempt to test the public authority and to see what happen if the legal requirements are not met. This will result in a number of low quality solar systems, possibly leading to a reduced acceptance of the obligation or even of solar energy as such. Therefore, a clear, realistic and strong sanctioning regime should be established and applied after all control phases discussed in the previous.

4.3. Quality assurance system

The purpose of setting up the quality assurance system is to ensure that the cheapest possible solution will provide required solar energy for a long time.

Within solar obligations, due to the enhanced quality needs, requiring a certification for the solar collectors is strongly recommended. At present, there are three third-party certification organizations for SWHs in China, however, most local regulations did not require the certification for solar collectors and systems.

Installation mistakes are the most common reason of failures in solar systems, therefore most local regulations contained requirements for the qualification of the solar system installers. Furthermore, solar obligations should require installation companies to sign a commissioning check list, to supply a minimum guarantee and after-sale service, and to provide necessary information about the solar system for users.

To our knowledge, no solar obligations in local regulations except Ningbo's contained the function monitoring and third party inspections. However, the installation of measuring and monitoring devices and random inspections for installed systems by qualified third party experts will create a powerful incentive for the companies to provide high quality products, installation and services.

In brief, a complete quality assurance system should include component and system certification, installation works, guarantee and after-sale service, function monitoring and controlling, as well as third party inspections.

4.4. Support measures for solar obligations

Not only to maximize the effect of solar obligations in the obliged sector but also to promote the use of solar in buildings not subject to the obligation, some support measures are necessary, especially at the early stage of implementation. Financial subsides, awareness raising, intensive training, and demonstration projects are usual flanking measures. As above mentioned, however, 16 provinces and cities did not adopt any support measures, and 7 provinces and cities adopted only one or two.

In light of the analysis above, financial subsides and demonstration projects were adopted as support measures at local and national level, and some effect has been achieved. Furthermore, these measures should continue and other financial incentives for the corporation and personal, such as tax credit and loan program, should be taken into consideration.

Within a solar obligation, if constructors, building administrators, architects, engineers, installers sufficiently trained, they will deal with solar energy at an advanced level and will become motivated to utilize solar energy beyond legal requirements. Therefore, training and awareness raising are strongly recommended at the first phase of implementation of a solar obligation.

4.5. Technical standard system

Technical standards are not the main component of solar obligations, but technical specifications required in standards are essential to ensure the solar obligation reach desired results, and as a technical basis for the quality assurance procedures and sanctions mentioned in the previous. Therefore, a complete technical standard system should contain quantitative and qualitative requirements for (i) quality aspects and the system performance and output of solar system and its components, (ii) the quality of the installation/installer, (iii) function control, and (iv) information to the user on commissioning checks, system operating conditions and installation guarantees.

At present, 17 national standards have been enacted for the quality of solar collectors and the design, construction/installation and acceptance of solar water heating systems. Meanwhile, 13 provinces and 3 municipalities have issued local technical standards, while few of them defined the calculation method for the fulfillment and set quantitative and qualitative requirements for the function control and installation guarantees. Therefore, not only national but also local standards should be constantly improved.

In addition, great differences in climatic conditions, technical level and economic level result in a regional imbalance in the development of solar thermal industry in China. Even though some provinces are rich in solar energy resources, such as Tibet, Xingjiang, and Inner Mongolia, the public awareness and knowledge about energy efficiency and solar energy was weak and the local SWH markets were underdeveloped because the economic and social development in these regions started at a low level. While in provinces and municipalities without abundant solar resources, such as Guangdong, Zhejiang, Shanghai and Jiangsu, local governments made efforts to popularize the solar water heating systems integrated with buildings and the local SWH markets have been preliminarily formed. To design solar obligations most suitable for the whole of China, therefore, policy makers should consider regional differences in the building stock, the regulatory and legal background, the level of economic development, the people's living standard, the typical training level of installers and so on.

5. Conclusion

China is abundant in solar energy resources and has become the biggest SWH production, sale and holding country in the world. Chinese government has formulated a series of laws and regulations to encourage the utilization of renewable energies during the past 10 years, especially solar thermal energy in civil buildings. Meanwhile, corresponding technical standard system and quality management system have initially formed. To further promote the use of solar thermal energy, many local governments have adopted solar obligations since 2006 and good results were obtained in some provinces and cities. Therefore, it is time for China to implement solar obligation in the whole country. According to lessons from abroad and domestic practices, a national solar legislation, including solar obligation, controlling procedures, sanctions, quality assurance measures and support measures, should be designed by the central government after consulting related professional associations, local and national energy agencies, governmental and public bodies, and so on. Once the national obligation enters into force, significant growth of solar thermal and reduction of greenhouse gas emission can be expected.

Acknowledgements

The authors are grateful for the support provided by the Ministry of Housing and Urban-Rural Construction of the People's Republic of China (Grant No. 2010-R1-19) and the International Copper Association.

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